

**NBSIR 73-295**

# **Interim Report No. 7. Chemical Resistance and Physical Durability Testing of Coating Materials**

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Nonmetallic Coatings for Concrete Reinforcing Bars

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Institute for Applied Technology  
National Bureau of Standards  
Washington, D. C. 20234

August 1973

Interim Report for Period  
April – June 1973

Prepared for  
**Federal Highway Administration**  
**U. S. Department of Transportation**  
Washington, D. C. 20590



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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary  
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director



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Interim Report No. 7  
Chemical Resistance and Physical Durability  
Testing of Coating Materials

1. Project Information. Order No. 2-1-0614 Title: Nonmetallic Coatings for Concrete Reinforcing Bars.

Date Project Initiated. 9-17-71

Research Agency. National Bureau of Standards

2. Introduction

2.1 Background. The early deterioration of the concrete of bridge decking, due to the corrosion of steel reinforcing bars, has become a major problem during the past decade. The annual cost of repairing bridge decks damaged in this manner is probably over 70 million dollars.

Normally, reinforcing steel is passive to corrosion when in an environment of the high basicity inherent in portland cement concrete. Chloride ions, however, are able to depassivate steel and thereby promote the active corrosion of steel.

Sodium chloride and calcium chloride are extensively used as de-icing agents on highways and bridges. When dissolved in water, these de-icing agents permeate through concrete decks to the regions where reinforcing bars are located. This leads to the corrosion of steel and subsequent cracking and spalling of the concrete. The amounts of sodium chloride and calcium chloride used as de-icing agents has increased substantially during the past decade.

2.2 Objectives. To investigate the protective qualities of organic coatings, especially epoxy systems, and to select the most promising materials for corrosion protection of concrete reinforcing bars, **the**

selection to be based upon physiochemical testing with consideration given to the economics involved in coating and fabrication.

### 3. Discussion of Activities

The long-term chemical-resistance and chloride-permeability testing of coating materials has been completed and the final results are given in this report, along with the results of indentation-hardness and impact-resistance determinations of coating on reinforcing bars. The corrosion testing and structural-type testing (creep) is continuing, and will be mentioned.

Descriptions of the coating materials selected for evaluation in this work are listed in table 1. The methods of selecting and procuring the materials are discussed in NBS Report 10968 [1]. The techniques of preparing or obtaining test specimens (epoxy discs, coated rebars, thin epoxy films, etc.) were also described in NBS Report 10968 and will not be repeated in this current report.

Grade 60, No. 6 steel reinforcing bars were used exclusively throughout this project.

#### 3.1 Chemical Resistance Testing

3.1.1 Epoxy Disc Specimens. Disc shape castings of cured epoxy specimens (liquids in their uncured states) were each immersed in the following: in water, in an aqueous solution of 3M  $\text{CaCl}_2$ ; in an aqueous solution of 3M  $\text{NaOH}$ ; and in a solution saturated with both  $\text{Ca}(\text{OH})_2$  and  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  which also contained 0.5M  $\text{CaCl}_2$ . The specimens were immersed in water for a few minutes and wiped dry before measuring the original weights. Original weights of the discs varied from ca. 20 grams for solvent-containing systems to ca. 50 grams for the solventless epoxy

systems. The temperatures of the test solutions were  $24 \pm 1^\circ\text{C}$ .

The specimens were immersed for over a year and the final immersion data are presented in table 2. In some cases two separate castings were made; indicated by two sets of data with different immersion times. In general, weights of the specimens changed by less than  $\pm 4$  percent. The epoxies which in their uncured state contained solvents, generally lost weight and had greater weight changes than the solventless epoxies. In contrast to most specimens, Nos. 4, 9, and 16 gained weight in the NaOH and lost weight in the other solutions. An exception to the solvent containing epoxies is No. 7, which had the largest weight increase (13 to 19 percent) of all epoxies studied. The surfaces of both No. 7 and No. 9 specimens were converted from smooth to rough textures during the immersion period. No apparent deterioration was observed with the other epoxy specimens.

The weight losses of solvent-containing epoxies possibly may be associated with the gradual loss of retained solvents. Large weight increases may be indicative of porosity or swelling.

3.1.2 Coating on Reinforcing Bars. The chemical resistances of powdered epoxy systems were investigated by immersing coated reinforcing bars in aqueous solutions of 3M NaOH and of saturated  $\text{Ca}(\text{OH})_2$ . The coatings were inspected for evidence of softening, color change, disbonding and changes in film integrity. The data are presented in table 3 for three polyvinyl chloride coatings, Nos. 23, 24, and 30; one pseudo-powder epoxy, No. 19; 10 powder epoxy coatings; and uncoated bars.

The rusting of some coated reinforcing bars and the uncoated bars in saturated  $\text{Ca}(\text{OH})_2$  solutions is an interesting phenomenon, especially

since the corrosion was only observed in the weaker alkaline solution, i.e. saturated  $\text{Ca}(\text{OH})_2$  rather than 3N NaOH. The pH of saturated  $\text{Ca}(\text{OH})_2$ , however, is near 13 which is sufficient to passivate steel. Therefore, the cause of the corrosion apparently lies in either the surface preparation or in the composition of the coatings. Note that the surfaces of the rusting specimens of numbers 38, 39 and 40 were phosphatized before the epoxy was applied. Also, it was noted that the epoxy over the phosphated surfaces had softened during immersion. The surfaces of the companion non-rusting specimens were only sand blasted and the epoxy film had not softened. It is not obvious at this date why the same rusting phenomenon was not observed when the rebars with various surface preparations were immersed in the 3M NaOH.

3.2 Chloride Permeability. The chloride permeability characteristics of thin films (3 - 7 mils) of cured epoxies have been measured by the methods described in NBS Report 10968 [1]. The final data are presented in table 4. Many of the epoxy films, Nos. 1, 17, 19, 31 and 39, appear to be essentially impervious to chloride ions. Only two films, Nos. 13 and 16, permitted sufficient chloride ions to migrate through so that the corrosion threshold concentration of 0.2 M [2] was reached.

### 3.3 Impact Test

The resistance of coatings on reinforcing bars to mechanical damage was assessed by the falling weight method. A test apparatus similar to that described in ASTM Designation G14-69T [3] was used along with a four pound tup. Impact occurred on the low-lying areas on the coated bars, i.e. areas between the deformations. The test was performed at 25°C.

The type and extent of damage to the coating caused by impact of 120 in-lb was visually assessed and the area of damage was measured. The data are listed in table 5. It has been concluded, arbitrarily, that the area of damage on a acceptable coating for rebars should not exceed  $0.15 \text{ in}^2$  for a 120 in-lb impact.

### 3.4 Hardnesses of Coatings

The microhardness of coatings on steel reinforcing bars were measured by the indentation method, using an apparatus of the type described in ASTM Designation D1474-68 [4], and following the methods outlined therein. A 10 gram load was used.

The Knoop Hardness Number (KHN) was calculated with the equation:

$$\text{KHN} = \frac{L}{A_p} = \frac{L}{\ell^2 C_p}$$

where L is the load applied to the indenter in kilograms;  $\ell$  is the measured length of the long diagonal of the indentation in the coating in millimeters;  $C_p$  is a constant with the value of  $7.028 \times 10^{-2}$ ;  $A_p$  is the projected area of the indentation.

The results for five coatings on rebars are given in table 6. No. 30 is a polyvinylchloride and has a relatively low hardness of 6.7 KHN, while the other four coatings are powder epoxies having hardnesses above 18 KHN. No. 22 and No. 31 are rebars coated with the same epoxy material but applied by different methods yielding different film thicknesses. The film thickness of No. 22 is ca. 25 mils (applied by the fluidized bed technique), while the film thickness of No. 31 is ca. 8 mils (applied using electrostatic spray gun). The microhardness was determined to be 20.7 KHN for both coating films; therefore, it seems that the microhardness of the

coating film alone was being measured and not the composite hardness of the coating and the steel substrate.

### 3.5 Corrosion Studies of Coated Reinforcing Bars Embedded in Concrete

The protective qualities of coating materials are also being evaluated by corrosion studies of coated rebars embedded in concrete specimens. These specimens have been partially immersed in an aqueous solution of 3.5 percent NaCl. Any corrosion occurring is being monitored by taking both electrical potential and electrical resistance measurements. The fabrication of test specimens and the method of testing have been previously described [5].

The current data are presented in table 7. No evidence of cracks developing in the concrete cover nor of rust stain have been observed.

### 3.6 Creep Tests

The creep characteristics of coated steel reinforcing bars embedded with one end in concrete prisms and loaded under tension are being assessed and compared to the creep of uncoated reinforcing bars embedded and loaded in the same manner. The work in this reporting quarter involved loading the creep specimens and recording the initial measurements. The fabrication of test specimens and preparation of the test apparatus have been covered in a previous report [5].

Two levels of tensile stresses in the steel reinforcing bars, 15,000 and 30,000 psi, are being exerted by the compression of steel coil springs. The tensile stress in the rebar for each creep specimen is listed in table 8. Strain gages, with small intrinsic creep properties, and measurements of the changes in length of the compressed springs are being used for monitoring tensile loads in the rebars [5]. Both the

free and loaded-end slip of the reinforcing bars embedded in the concrete prisms are being measured with dial gages.

The tests were just commenced at the end of this reporting quarter. Possibly, sufficient data will be available in the next reporting quarter to make tentative interpretations of the creep characteristics of coated and uncoated rebars.

### 3.7 Qualification Specifications

Qualification specifications that cover the requirements new coatings must meet for approval as acceptable coating for steel reinforcing of concrete bridge decks have been drafted by the NBS staff and forwarded to the FHWA.

### 3.8 Talk Based on Project

The following talk based on the project was given by Dr. James R. Clifton:

"Organic Coatings for the Protection of Steel Reinforcement in Concrete Bridge Decking," staff meeting of the Center for Building Technology of NBS, April 19, 1973.

### 3.9 Pertinent Visits by NBS Staff

1. Dr. Clifton and Mr. Beeghly visited the Westinghouse Power Cooling Systems Department, Media, Pennsylvania, on April 25, 1973, to discuss the use of epoxy coated reinforcing bars in the reinforced concrete of power plant cooling towers.

2. Mr. Beeghly visited H. C. Price Company, Fairless Hills, Pennsylvania on May 31, 1973, to witness the applications of a powder epoxy coating of duPont Company to rebars on a production-line basis. This production run was performed for the duPont Company and the Bethlehem Steel Company.

3. Mr. Beechly visited Taylor-Davis Company, Wilmington, Delaware, on June 5, 1973, to observe fabrication (bending, and cutting to size) of the bars coated by Price on May 31, 1973. The coating was only slightly damaged by the fabrication process.

#### 4. Status of Project

All of the tests specified in the project-contract are either completed or are currently being performed.

#### 5. Problems

It is the opinion of the NBS staff that both the creep and corrosion testings of reinforcing bars embedded in concrete should be continued until either the specimens fail or unequivocal test results are obtained. This will certainly necessitate continuance of these tests beyond the contract expiration date of September 30, 1973. It is recommended that these studies continue for at least one year beyond the contract expiration date.

#### 6. Work Planned for the Next Quarter

The corrosion testing and creep testing of coated and uncoated reinforcing bars embedded in concrete will be continued.

Many of the drawings, photographs and tables to be included in the final report will be prepared.

Studies on the protective qualities of epoxy coatings on rebars will be completed and the results analyzed.

## References

1. J. Clifton, H. Beeghly and R. Mathey, "Interim Report No. 4, Screening Tests for Evaluating Materials." NBS Report 10968 (1973).
2. D. A. Hausman, "Steel Corrosion in Concrete," Materials Protection, 6, 19 (1967).
3. ASTM Designation 614-69T, Impact Resistance of Pipeline Coatings (Falling Weight Test).
4. ASTM Designation D 1474-68, Test for Indentation Hardness of Organic Coatings.
5. J. Clifton, H. Beeghly, E. Anderson and R. Mathey, "Interim Report No. 6, Corrosion and Creep Testing of Coated Reinforcing Bars in Concrete," NBS Interagency Report 73-229 (1973).

TABLE 1 COATING MATERIALS

Code Number	Type	Uncured State	Comments
1	Epoxy-Polyamide	Liquid - 100 percent solids	Used for concrete overlays
2	Epoxy-Polyamide	Liquid - 100 percent solids	Has been previously tested as coating for steel rebars
3	Epoxy-Polyamide	Liquid - 100 percent solids	Primer
4	Epoxy-Modified amine	Liquid - 100 percent solids	Primer
5	Epoxy-Polysulfide	Liquid - 100 percent solids	Used to bond fresh concrete to old concrete
6	Epoxy-Modified amine	Liquid - 100 percent solids	Topcoat
7	Epoxy	Liquid - 50 percent solids	Water emulsion activated system
8	Epoxy-Polyamide	Liquid - 60 percent solids	--
9	Epoxy-Polyamide	Liquid - 50 percent solids	Primer
10	Epoxy-Ketamine	Liquid - 100 percent solids	High Viscosity
11	Epoxy-Ketamine	Liquid - 100 percent solids	--
12	Epoxy	Liquid - ca. 100 percent solids	Cures at relative humidity above 50 percent
13	Epoxy	Liquid - ca. 100 percent solids	Limited flexibility
14	Vinyl	Liquid - 20 percent solids	Primer paint
15	Epoxy-Polyamide	Liquid - 50 percent solids	Epoxy paint
16	Epoxy-Polyamide	Liquid - 50 percent solids	Epoxy paint
17	Epoxy	Liquid - 100 percent solids	Low Viscosity
18	Coal tar epoxy	Liquid - 100 percent solids	Protective overlay on concrete pavements
19	Epoxy	Liquid - 46 percent solids	One component, cures by heating
20	Epoxy	Powder	Only coated rebars have been received
21	Epoxy	Powder	Only coated rebars have been received
22	Epoxy	Powder	Only coated rebars have been received
23	Polyvinylchloride	Powder	Only coated rebars have been received
24	Polyvinylchloride-Plastisol	Powder	Only coated rebars have been received
25	Epoxy	Powder	--

TABLE 1 COATING MATERIALS (cont.)

Code Number	Type	Uncured State	Comments
26	Polyvinylchloride	Powder	Only coated rebars have been received
27	Epoxy	Powder	--
28	Epoxy	Powder	--
29	Epoxy	Powder	--
30	Polyvinylchloride	Powder	Only coated rebars have been received
31	Epoxy	Powder	Same material as No. 22, but coated rebars submitted from a different applicator and also the pure powder was submitted.
32	Epoxy	Powder	--
33	Polyurethane	Liquid	Only coated rebars have been received
34	Phenolic nitrile	Liquid - 10 percent solids	Adhesive for metals
35	Polyurethane	Liquid - 100 percent solids	Elastomer, elongation - 600 percent
36	Polyurethane	Liquid - 100 percent solids	Elastomer, elongation - 550 percent
37	Epoxy	Liquid - 100 percent solids	Adhesive for metals
38	Epoxy	Powder	--
39	Epoxy	Powder	--
40	Epoxy	Powder	--
41	Epoxy	Powder	Only coated rebars have been received
42	Epoxy	Powder	Only coated rebars have been received, same material as No. 41, but different application procedure.
43	Epoxy	Powder	--
44	Zinc filled-zinc silicate	Liquid - 80 percent solids	Metallic zinc filler and liquid base are mixed, hardens by solvent evaporation.
45	Coal tar epoxy	Liquid	One component, epoxy resin and coal tar, no curing components.
46	Epoxy-Polysulfide	Liquid	--
47	Polypropylene	Powder	Only coated rebars have been received. Coating very brittle.

TABLE 2 WEIGHT CHANGES OF CURED EPOXY DISCS IMMersed IN AQUEOUS SOLUTIONS

Code Number	Immersion Time (Weeks)	PERCENT WEIGHT CHANGES				Saturated $\text{Ca}(\text{OH})_2$ , saturated $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ and 0.5M $\text{CaCl}_2$
		Water	3M $\text{CaCl}_2$	3M NaOH		
1	66	2.3	1.7	2.5		3.5
	53	4.2	1.2	3.9		4.6
2	66	4.2	2.5	3.6		5.2
	53	3.9	2.7	3.8		3.2
3	66	-2.3	-2.4	1.8		-3.0
	53	-3.2	-3.5	3.7		-3.9
4	66	2.9	1.5	2.1		2.6
	53	2.5	1.2	2.2		2.4
5	66	1.5	1.3	2.1		2.1
	53	1.8	0.8	0.7		1.7
6	66	3.7	1.8	2.8		3.6
	53	3.0	1.5	2.5		3.2
7	66	16	19	13		18
8	66	-9.1	-6.3	-2.7		-5.5
9	66	-6.8	-10	5.3		-13
12	64	1.5	1.0	2.1		2.0
13	64	3.3	1.0	2.5		2.5
16	57	-0.8	-2.3	0.4		-2.0
	53	-3.6	-4.2	0.9		-4.5
17	59	3.3	1.0	3.0		3.9
	53	2.6	1.2	2.7		2.6
18	59	0.8	0.2	0.9		0.9
	53	1.0	0.5	1.0		1.1

TABLE 3 IMMERSION TESTING OF COATINGS ON REINFORCING BARS<sup>1/</sup>

Code Number	3N NaOH <sup>2/</sup>	Saturated Ca(OH) <sup>2/</sup>
19	No Change	A. Very Badly Rusted <sup>3/</sup> <u>5/</u> B. Badly Rusted <sup>3/</sup>
22	No Change	No Change
23	No Change	No Change
24	No Change	No Change
25	No Change	No Change <sup>6/</sup>
27	No Change	No Change
28	No Change	Slightly Rusted
29	No Change	Slightly Rusted
30	No Change	No Change
31	No Change	No Change
32	No Change	No Change
38	No Change	B. Rusted <sup>4/</sup> <u>5/</u> P. Rusted <sup>4/</sup> <u>5/</u>
39	No Change	B. No Change <sup>4/</sup> P. Rusted <sup>4/</sup> <u>5/</u>
40	No Change	B. No Change <sup>4/</sup> P. Rusted <sup>4/</sup> <u>5/</u>
41	No Change	No Change
Uncoated Rebar	No Change	Rusted

<sup>1/</sup> No. 6 reinforcing coated by firms handling the respective coatings.

<sup>2/</sup> Immersion time of 270 days.

<sup>3/</sup> A and B are specimens from companion bars.

<sup>4/</sup> B denotes bars that were only sandblasted prior to application of the coating, while P indicates that their surfaces were also phosphatized prior to being coated.

<sup>5/</sup> Rusting took place during the first 15 days of immersion; afterward rusting lifted most of epoxy from bar.

<sup>6/</sup> No rust. Numerous small blisters, apparently caused by penetration of water through coating, had been formed.

TABLE 4 PERMEABILITY OF CHLORIDE IONS THROUGH EPOXY FILMS

Code Number	Film Thickness (mils)	Exposure Time (weeks)	Concentration <sup>1/</sup> (Moles per liter)
1	3	50	$1 \times 10^{-5}$ <u>2/</u>
2	3	23	$1 \times 10^{-4}$
3	3	16	$<1 \times 10^{-5}$ <u>2/</u>
4	3	23	$1 \times 10^{-4}$
6	3	23	$1 \times 10^{-4}$
11	3	12	$4 \times 10^{-3}$
13	3	21	$1 \times 10^{-2}$
16	7	23	$2 \times 10^{-3}$
	3	10	$8 \times 10^{-1}$
17	3	50	$<1 \times 10^{-5}$ <u>2/</u>
19	7	37	N.C. <sup>3/</sup>
29	10	37	
31	10	37	N.C.
38	2.5	39	$1 \times 10^{-3}$
39	2.5	39	N.C.
40	2.5	39	$1 \times 10^{-3}$

1/ Concentration of chloride ions in the chamber originally containing only distilled water.

2/ Millivolt readings were near the region of distilled water and the lower limit of the chloride ion concentration was estimated.

3/ N.C. denotes that no changes from the original millivolt values were measured.

TABLE 5 IMPACT RESISTANCE OF COATINGS ON REBARS  
(Impact of 120 in-lb)

Code Number <sup>1/</sup>	Film Thickness (mils)	Damaged Area <sup>2/</sup> (in <sup>2</sup> )	Type and Severity of Damage
2	5-15	.110	Shattering and disbonding of coating propagating from area of impact.
3	2-5	.028	Only indentation in coating and rebar at impact area.
4	10-20	.082	Shattering and disbonding of coating propagating from area of impact.
5	10-15	.383	Large amount of shattering and disbonding of coating surrounding area of impact.
10	10	.079	Shattering and disbonding of coating at impact area.
11	10-12	.188	Shattering and disbonding of coating propagating from area of impact.
16	2-4	.038	Slight shattering and disbonding of coating at impact area.
17	4	.028	Slight shattering and disbonding of coating at impact area.
18	4	.038	Slight shattering and disbonding of coating at impact area.
19	1	.028	Only indentation in coating and rebar at impact area.
22	25	.234	Large amount of shattering and disbonding of coating surrounding area of impact.
23	25	.077	Large indentation in coating.
24	35	.110	Large indentation in coating.
25	6-11	.049	Shattering and disbonding of coating at impact area.
27	8	.077	Coating shattered at area of impact with slight propagation of shattering from impact region.
28	1-2	.038	Slight shattering and disbonding of coating at impact area.

TABLE 5 IMPACT RESISTANCE OF COATINGS ON REBARS (cont.)

Code Number <sup>1/</sup>	Film Thickness (mils)	Damaged Area <sup>2/</sup> (in <sup>2</sup> )	Type and Severity of Damage
29	1-2	.028	Slight shattering and disbonding of coating at impact area.
30	15-18	.110	Large indentation in coating accompanied by slight cracking at impact area.
31	8-9	.110	Shattering and some disbonding of coating at impact area.
32	4-6	.049	Cracking in coating at impact area, slight cracking extending from impact region.
33	3-4	.028	Shattering of coating at impact area.
38	2-4	.038	Shattering of coating at impact area, slight cracking extending from impact region.
39	2-4	.028	Only indentation in coating and rebar at impact area.
40	2-4	.079	Shattering of coating at impact area, slight disbonding extending from impact region.
41	3-7	.038	Shattering of coating at impact area, slight cracking extending from impact region.
42	3-4	.028	Only indentation in coating and rebar at impact area.
43	3-4	.038	Smashing of coating at impact area, slight cracking extending from impact region.

<sup>1/</sup> Coatings on Number 6 steel reinforcing bars.

<sup>2/</sup> The maximum area struck by the tup is 0.27 in.<sup>2</sup> based on a diameter of 5/8 inch.

TABLE 6      INDENTATION HARDNESSES OF  
COATINGS ON REINFORCING BARS

Code Number	Hardness KHN <u>1/</u>
22	20.7
29	19.8
30	6.7
31	20.7
39	21.2

1/ Knoop Hardness Number

TABLE 7 ELECTRICAL POTENTIAL AND RESISTANCE MEASUREMENTS  
OF CORROSION-TEST SPECIMENS IN AQUEOUS SOLUTION  
OF 3.5 PERCENT NaCl.

Exposure Time (Hour)						
		24		3480		
Coating Code	No. <sup>1/</sup>	EMF (MV)	Resistance (ohms)	EMF (MV)	Resistance (ohms)	Protective Rating <sup>2/</sup>
1	A	-345.0	3.8 x 10 <sup>2</sup>	-283.0	3.9 x 10 <sup>2</sup>	3
	B	-408.8	7.0 x 10 <sup>2</sup>	-362.4	8.2 x 10 <sup>2</sup>	
1-1		-337.0	2.5 x 10 <sup>2</sup>	-215.0	2.5 x 10 <sup>2</sup>	-
1-S		-484.5	4.8 x 10 <sup>2</sup>	-371.5	4.2 x 10 <sup>2</sup>	-
3	A	-285.6	3.1 x 10 <sup>2</sup>	-432.4	2.2 x 10 <sup>2</sup>	3
	B	-260.3	2.7 x 10 <sup>2</sup>	-365.5	2.4 x 10 <sup>2</sup>	
4	A	-339.2	2.4 x 10 <sup>4</sup>	-142.3	1.1 x 10 <sup>5</sup>	3
	B	-130.0	1.0 x 10 <sup>5</sup>	-115.5	1.4 x 10 <sup>4</sup>	
18		-575.6	6.0 x 10 <sup>3</sup>	-003.0 <sup>3/</sup>	1.0 x 10 <sup>4</sup>	3
19	A	-484.0	5.6 x 10 <sup>2</sup>	-399.5	5.4 x 10 <sup>2</sup>	2
	B	-438.0	6.1 x 10 <sup>2</sup>	-282.0	6.0 x 10 <sup>2</sup>	
25		-542.7	4.1 x 10 <sup>2</sup>	-271.4 <sup>3/</sup>	5.1 x 10 <sup>2</sup>	1
27	A	-654.6	1.3 x 10 <sup>4</sup>	-167.0 <sup>3/</sup>	7.2 x 10 <sup>4</sup>	3
	B	-571.5	6.8 x 10 <sup>3</sup>	-542.0	1.1 x 10 <sup>4</sup>	
28		-461.5	5.2 x 10 <sup>2</sup>	-262.8 <sup>3/</sup>	5.4 x 10 <sup>2</sup>	3
29	A	-376.3	6.4 x 10 <sup>2</sup>	-163.0 <sup>3/</sup>	7.8 x 10 <sup>2</sup>	2
	B	-403.4	6.6 x 10 <sup>2</sup>	-360.5	5.4 x 10 <sup>2</sup>	
30	A	-058.0	1.0 x 10 <sup>5</sup>	N.C.	2.1 x 10 <sup>5</sup>	1
	B	-448.2	1.5 x 10 <sup>5</sup>	-127.4 <sup>3/</sup>	1.6 x 10 <sup>5</sup>	
31	A	-359.8	1.5 x 10 <sup>3</sup>	-038.5 <sup>3/</sup>	9.8 x 10 <sup>4</sup>	1
	B	-092.2	9.8 x 10 <sup>3</sup>	-013.5	6.2 x 10 <sup>4</sup>	
38		-392.7	3.2 x 10 <sup>2</sup>	-165.7	4.1 x 10 <sup>2</sup>	3
39-Phos	A	-513.0	4.9 x 10 <sup>2</sup>	-348.0	4.7 x 10 <sup>2</sup>	3
	B	-536.2	5.0 x 10 <sup>2</sup>	-402.0	4.8 x 10 <sup>2</sup>	
40-Phos	A	-282.2	2.5 x 10 <sup>2</sup>	-256.6	2.2 x 10 <sup>2</sup>	2
40-Phos	B	-382.5	3.4 x 10 <sup>2</sup>	-325.5	2.7 x 10 <sup>2</sup>	
40	A	-431.8	2.9 x 10 <sup>2</sup>	-398.0	3.1 x 10 <sup>2</sup>	3
	B	-377.0	2.8 x 10 <sup>2</sup>	-316.9	2.3 x 10 <sup>2</sup>	
41	A	-540.5	6.0 x 10 <sup>3</sup>	-432.2	1.3 x 10 <sup>4</sup>	2
	B	-575.9	5.4 x 10 <sup>2</sup>	-324.4	2.5 x 10 <sup>4</sup>	
Uncoated	A	-334.2	2.7 x 10 <sup>2</sup>	-206.6	2.3 x 10 <sup>2</sup>	4
	B	-264.0	2.6 x 10 <sup>2</sup>	-180.3	2.2 x 10 <sup>2</sup>	

<sup>1/</sup> A and B denote duplicate specimens.

<sup>2/</sup> Ratings from Table 8 of reference [1].

<sup>3/</sup> Large shifts in electrical potential attributed to sealing small holes in the silicone seal.

TABLE 8 CREEP TEST SPECIMENS

Specimen No.	Coating No.	Stress in Rebar <sup>1/</sup> (psi)	Concrete Batch No. <sup>2/</sup>
1	19	30,000	2
2	U.C. <sup>3/</sup>	30,000	2
3	39	30,000	2
4	39	15,000	2
5	U.C.	15,000	1
6	30	30,000	1
7	38	30,000	2
8	31	30,000	2
9	25	15,000	1
10	30	15,000	1
11	U.C.	30,000	1
12	25	30,000	1
13	1	15,000	2
14	31	15,000	2
15	41	30,000	1
16	29	30,000	1
17	38	15,000	2
18	U.C.	30,000	2
19	19	15,000	2
20	29	15,000	1
21	41	15,000	1
22	18	30,000	1
23	1	30,000	2
24	18	15,000	1

<sup>1/</sup> Tensile stresses in the steel reinforcing bars

<sup>2/</sup> Identification of batch of concrete used to fabricate specimen

<sup>3/</sup> Denotes uncoated rebars



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